Hydro-geochemical investigations at an urban lysimeter of Union brewery, Ljubljana, Slovenia

B. TRCEK and A. JUREN

Abstract

An urban lysimeter was constructed within a highly urbanized environment at Union Brewery in Ljubljana (the capital of Slovenia) with the intention to study the possible contamination in the area of the brewery and with that to study the role of the unsaturated zone in the protection of groundwater of a Pleistocen alluvial gravel aquifer. The physical-chemical and isotopic properties of sampled groundwater have already produced the general information on the hydrodynamic functioning of the study area and the solute transport. Two important flow types were identified - the lateral and the vertical flow. The former has an important role in the groundwater protection, while the latter is the main factor for the contaminant transport towards the aquifer saturated zone.

Key words: urban lysimeter, Pleistocene alluvial gravel aquifer, flow system, solute transport

Introduction

Groundwater of a Pleistocen alluvial gravel aquifer is an invaluable water source for Union brewery, which is located within a highly urbanized and industrialized environment near the centre of Ljubljana and supplies a quality groundwater from four production wells (*Figure 1*). With regard that this water should be protected the flow and solute transport monitoring was restored in numerous piezometers within the brewery and in its vicinity, as well as at the lysimeter, which is a topic of this paper (*Figure 1*). The main goal of the lysimeter monitoring is to study the possible contamination in the area of the brewery and with that to study the role of the unsaturated zone in the protection of groundwater of a Pleistocen alluvial gravel aquifer.

Description of the study area

The urban lysimeter of Union brewery was constructed in the near brewery vicinity (*Figure 1*). 42 boreholes were drilled on the right and left side of the 8.5 m deep construction (*Figure 2*). As an example the projection of boreholes of the right upper level is demonstrated in *Figure 2*.

The right side of the lysimeter, which is located under the industrial railway tracks, includes 36 boreholes that are up to 8 m long. They are distributed into six columns (1-6) and six levels (I-VI) at depths 0.3, 0.6, 1.2, 1.8, 3.0 and 4.0 m (*Figures 2, 3*). The boreholes are named after their distribution: RI-1, RI-2,…..RVI-5, RVI-6.

Further six boreholes were drilled under an asphalt surface on the left lysimeter side (*Figure 2*). They are distributed into six columns (1-6) and three levels (I-III) at depths 0.60, 1.20 and 1.80 m. Hence,

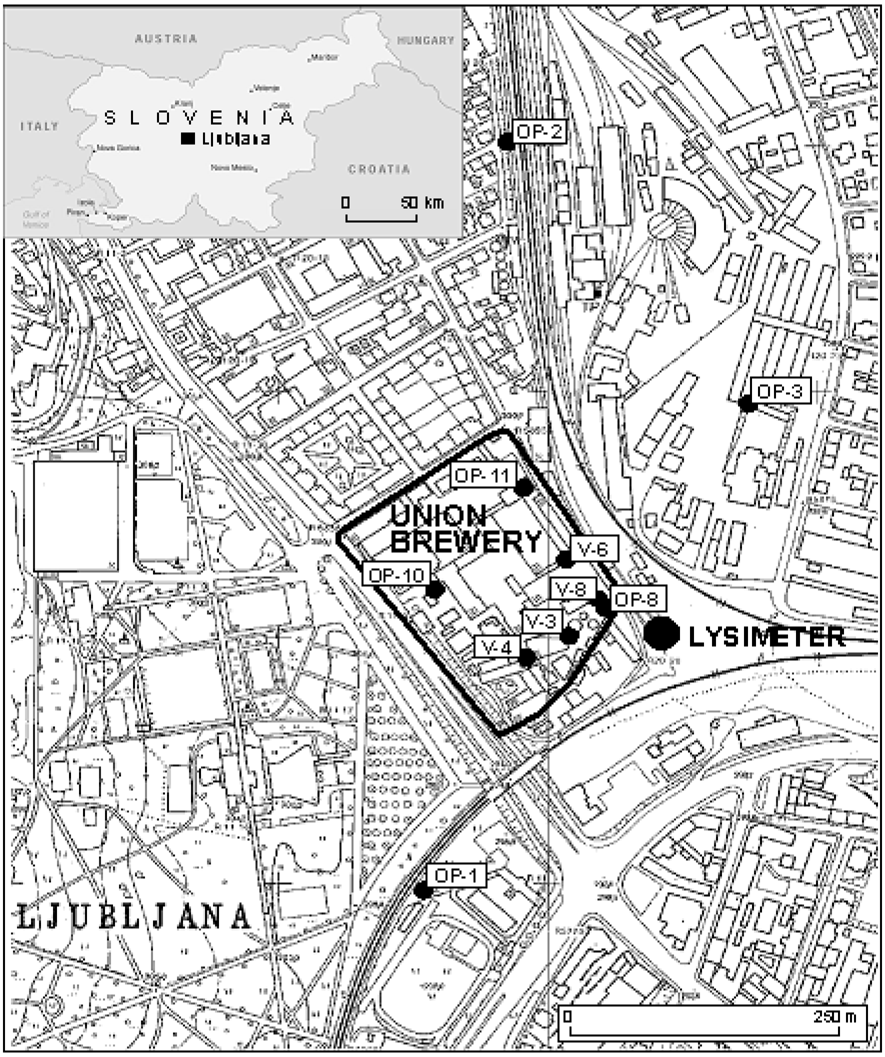

Figure 1: **Study area**

Autoren: Dr. Branka TRCEK, Geological Survey of Slovenia, Dimiceva ul. 14, SI-1000 LJUBLJANA and Andrej JUREN, Geosi Geological Institute d.o.o., Kebetova 24, SI-1000 LJUBLJANA

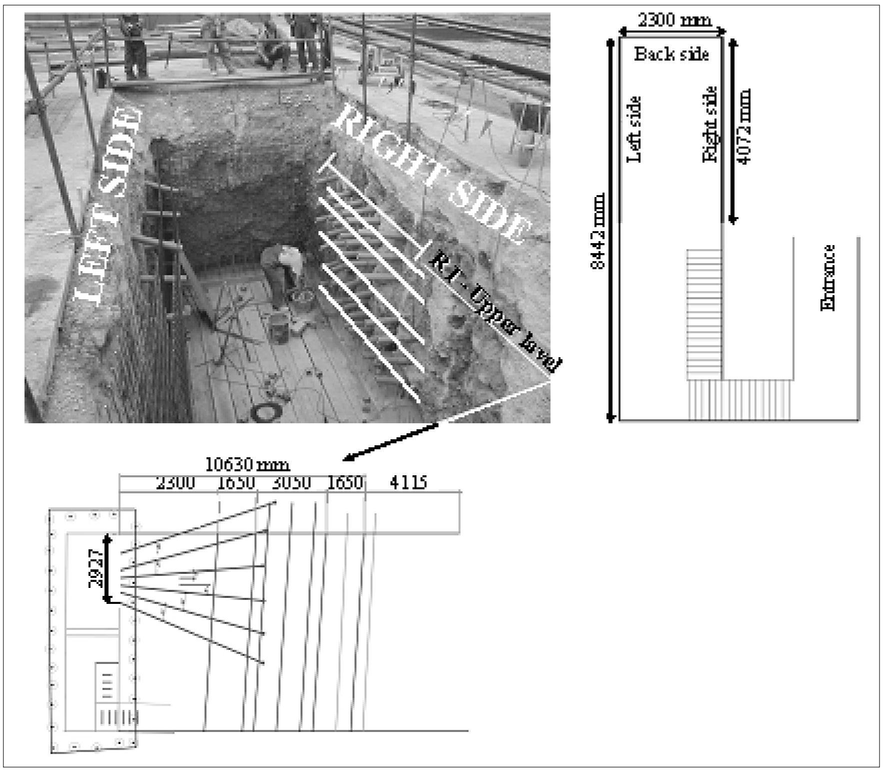

Figure 2: **Lysimeter construction with the projection of the upper right level boreholes RI/1-6.**

Table 1: **Position of measuring probes installed in the lysimeter boreholes (■ - installed suction cups, • - installed TDR probes, o - installed tensiometers).**

right side	column 1	2	3	4	5	6
RI	■	■	■	•	o	o
RII	■	■	■	•	o	o
RIII	■	■	■	•	o	o
RIV	■	■	■	•	o	o
RV	■	■	■	•	o	o
RVI	■	■	■	•	o	o

left side	column 6	5	4	3	2	1
LI			■ o			•
LII		■ o			•	
LIII	■ o			•		

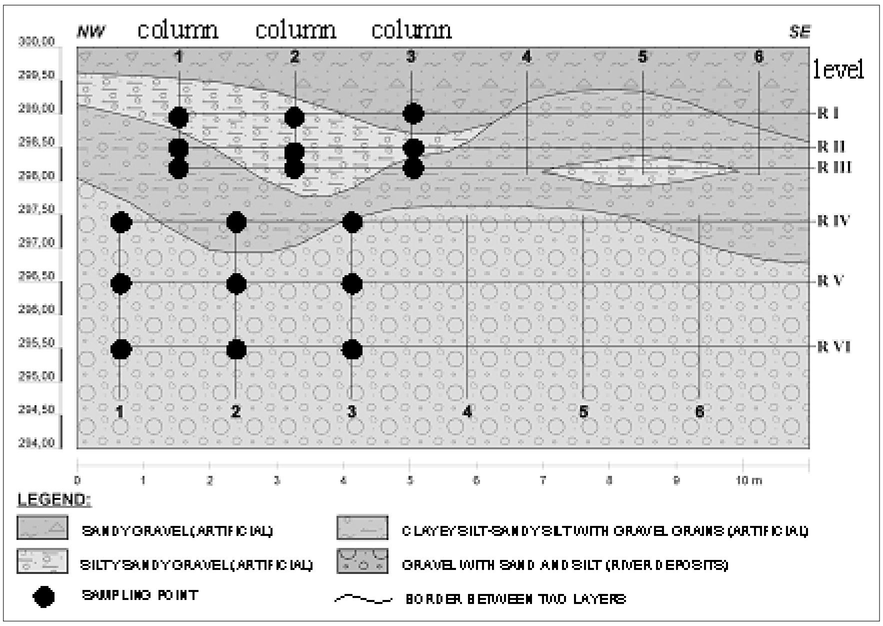

Figure 3: **Geological cross-section on the right side of the lysimeter at the end of boreholes, with sampling points (modified after JUREN et al., 2003).**

they are named LI-1, LI-2, ….. LIII-5, LIII-6.

At the beginning of January 2003 the lysimeter was completely equipped with the UMS environmental monitoring system - the recording and sampling system. 15 tensiometers, 9 TDR probes and 21 suction cups were installed into the boreholes, which is evidenced in *Table 1*.

The boreholes penetrate four layers: sandy gravel, silt-sandy gravel, clayey silt-sandy silt with gravel grains and gravel with sand and silt. The upper three layers are artificial, while the fourth layer consists of river deposits. The detailed geological cross-section at the end of the boreholes on the right side of the lysimeter is presented in *Figure 3*.

Methods and techniques

At the lysimeter the monitoring of flow and solute transport processes started in June 2003. During the first research year the continuous measurements of hydrodynamic parameters (capillary pressure and water content), of water balance and of water physical-chemical parameters (pH and electroconductivity) were carrying out to get the basic information of the study area. Besides the monthly water sampling for analyses of the ^{18}O and ^{2}H isotopic composition was performed to establish additional information about the mixing processes and the ground water residence time in the unsaturated zone.

The groundwater was sampled with suction cups installed at the end of the boreholes. The right side of the lysimeter includes 18 sampling points: RI-1 to RI-3, RII-1 to RII-3 and RIII-1 to RIII-3 (*Table 1*, *Figure 3*). However, the left side of the lysimeter includes only 3 sampling points: LI-4, LII-5 and LIII-6 (*Table 1*). Besides, the precipitation was sampled near the entrance to the lysimeter.

Results

For the first research period the water balance of the lysimeter sampling points is presented in *Table 2*. It could be observed in the table that the sampling points RII-2 and RIII-3 have the highest volume values and that on the right and left side of the lysimeter the bulk of wa-

Table 2: **Water balance of the lysimeter sampling points.**

	Volume (ml) RII 1	RV 1	RI 2	RII 2	RIII 2	RIV 2	RVI 2	RI 3	RIII 3	RIV 3	RV 3	RVI 3	LIII 6	Vol.(mm) Precipitation
10.07.03	280	340	86	41		70	19	455		110	45	160	5	57.7
27.08.03	385	490	38	45		95	38	370		45	65	38		71.6
17.09.03	175	175	21	20		50		220			40		38	44.5
16.10.03	380	200	110	24		890	29	190		100	24	40	37	110.7
12.11.03	190	180	100	20		60	55	180			20	30		121.4
09.12.03	190		60	20		60		120					20	73.8
20.01.04	280		20			80		90						150.3
17.02.04	180	10	35	20		48		25		27	7	7	10	12.7
25.03.04	230	30	190			50		40				35	20	122.5
15.04.04	420		110		49936	620			75580	40			25	94.3
12.05.04	190	23	25	27	79590	40		20	92550		20	35	5	64.8
15.06.04	520	10	30	20	76880	510		110	136210	50	20	30	25	83.1
13.07.04	210	40	100	20	81140	50		150	125330		30	30	15	133.0
11.08.04	220	25	80	22	89320	70			132530		70	50	20	89.2
total volume	3420	1485	825	237		2573	141	1820		372	241	375	185	1007.4

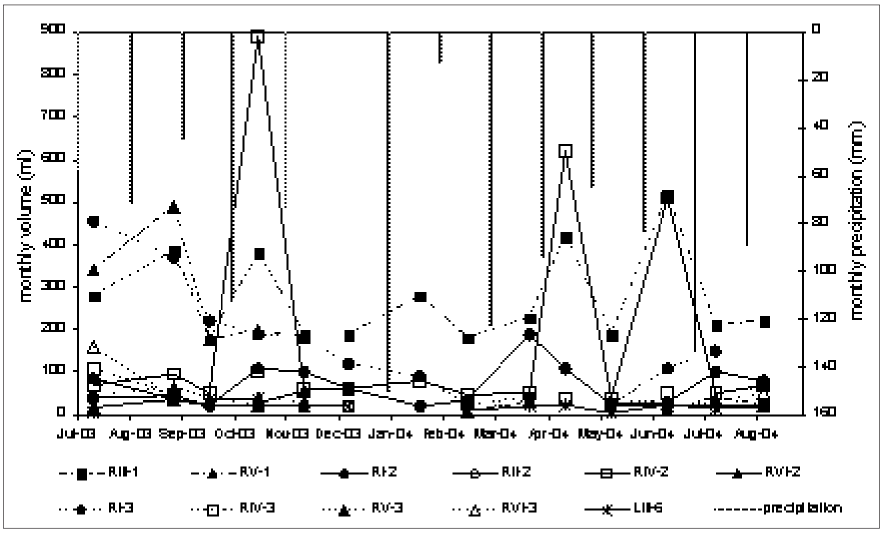

Figure 4: **Monthly volume of the lysimeter sampling points.**

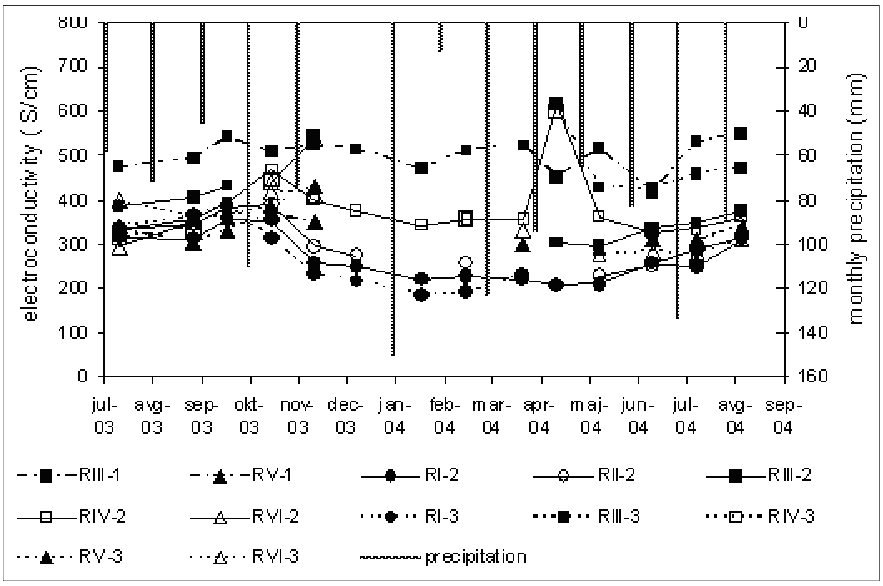

Figure 5: **Time-trend of the electroconductivity of water sampled on the right side of the lysimeter.**

ter is discharged to sampling points of the level III. It is important to notice that a low discharge arise also under the asphalt surface (LIII-6).

Figure 3 illustrates that the sampling points of the level III are located near the border between two structurally different layers: silt-sandy gravel and clayey silt-sandy silt with gravel grains. The hydraulic conductivity of the upper layer is higher from the one of the lower layer. Therefore it is presumed that the described differences result into the acquisition of a lateral flow component. *Figure 4* also indicates the occurrence of the vertical flow from the level III, which results in the increased volume values of the lower levels' sampling points, particularly of RIV-2 (October 2003, April and June 2004).

The electroconductivity of waters sampled on the lysimeter right side ranges from 180 to 615 µmS/cm. Quite higher values were measured on the lysimeter left side - up to 4000 µmS/cm. They most probably result from the winter contamination.

At the lysimeter the lowest electroconductivity values are connected with the levels I and II (*Figure 5*). However, the highest values are connected with the level III (*Figure 5*), which reflects the important role of the lateral flow component near this level. On the other hand *Figure 5* also illustrates when and where the vertical flow component dominated. The vertical breakthrough of water of the level III into the level IV is particularly pointed out in April 04.

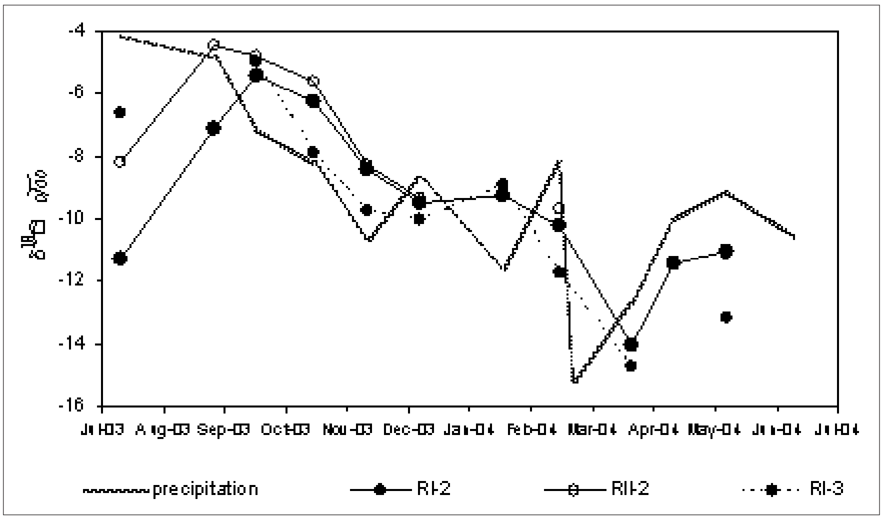

Figure 6: **Time-trend of $\delta^{18}O$ of water sampled in the lysimeter upper levels.**

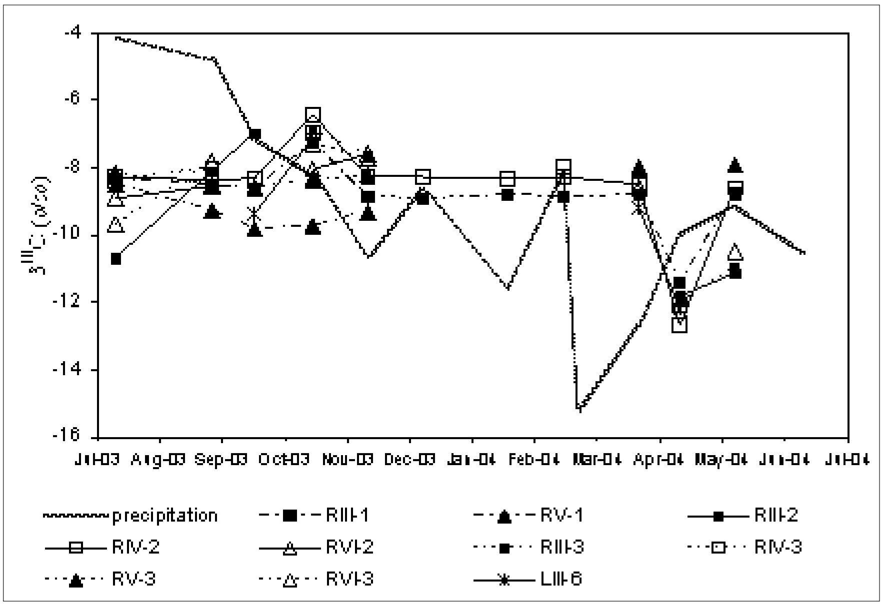

Figure 7: **Time-trend of $\delta^{18}O$ of water sampled in the lysimeter lower levels.**

The ^{18}O isotopic composition of sampled water is presented in *Figures 6* and *7*. The precipitation values range between -4.1 and -15.2 ‰ with the mean value at -8.9 ‰. The groundwater values vary between -4.5 and -14.7 ‰, while the means of single sampling points are between -8 and -10.7 ‰. The means as well as the spread of $\delta^{18}O$ of the lysimeter sampling points significantly distinguish among themselves. By comparison with precipitation the ranges of groundwater of upper two levels (I and II) are the highest, which reflects the intensive groundwater dynamics and short residence time (*Figure 6*). On the other hand the variation of the parameter is much more attenuated in the lysimeter lower levels (III, IV, V and VI), which should result from longer groundwater average residence time (*Figure 7*). The peak values in *Figures 6* and *7* indicate the vertical flow and solute transport in the aquifer during the significant hydrological events, i.e. in October 2003 and April 2004. For example, in April 2004 the precipitation pushed water of low $\delta^{18}O$ into the lysimeter lower levels (*Figure 7*). It is supposed that these values should result from the snow melting. The influences of the snow melting could be observed in the lysimeter upper levels one month before (*Figure 6*).

Discussion and conclusions

The results of the first research phase at the lysimeter of Union Brewery produced the general information on the hydrodynamic functioning of the study area and the solute transport. Two important flow types were identified - the lateral and the vertical flow. The lateral flow has an important role in the protection of groundwater of a Pleistocen alluvial gravel aquifer. However, the role of the vertical flow is quite opposite, because it is the main factor for the contaminant transport towards the aquifer saturated zone. Hence the study of the occurrence and frequency of such rapid recharge represents one of the main topics of the next research phases.

The presented results will help us to design and to upgrade the methodology of the further research, which will include also the tracer experiments and a short-term monitoring during the characteristic hydrological events like the storm events and the snow melting.

References

FANK, J., P. RAMSPACHER und H. ZOJER, 2001: Art der Sickerwassergewinnung und Ergebnisinterpretation. In Bericht der BAL über die Lysimetertagung, Gumpenstein, 16-17 April 1991: 55-62. Gumpenstein: BAL.

JUREN, A., M. PREGL and M. VESELIC, 2003: Project of an urban lysimeter at the Union brewery, Ljubljana, Slovenia. RMZ-Materials and Geoenvironment 50(3): 153-156.

KLOTZ, D., K.P. SEILER, I. SCHEUNERT und R. SCHROLL, 1999: Die Lysimeteranlagen des GSF-Forschungscentrums fuer Umwelt und Gesundheit. In: Bericht ueber die 8. Lysimetertagung: 157-160. Gumpenstein: BAL.

RAIMER, D., E. BERTHIER and H. ANDRIEU, 2003: Development and results of an urban lysimeter. Geophysical Research Abstracts 5: 37-92.

SEILER, K.P., S. LOEWENSTERN and S. SCHNEIDER, 2000: The role of by-pass and matrix flow in the unsaturated zone for the groundwater protection. In: Sililo et al. (eds.), Groundwater: Past Achivements and Future Challenge: 43-76. Rotterdam: Balkema.